maximum level o.6 dB less than the revised limit. The effect of this requested increase on the other services in the RDSS band are next examined.

Government Operations

Government operations are limited to radiolocation on a secondary basis in the 2450-2500 MHz band. Such use shall not cause harmful interference to non-Government users and Government users would have to accept interference from these primary users.

Effect on Grandfathered Operations

Stations in the private land mobile and operational fixed microwave services are authorized in the 2450-2500 MHz band on a shared basis and are offered no protection from ISM devices in the 2400-2500 MHz band. Stations licensed in the 2483.5-2500 MHz portion of the band as of July 25, 1985, or subsequently because of an application filed prior to that date, are grandfathered and may continue operations on a co-primary basis with the RDSS. Under Part 94, the band is nominally channelized at 625 kHz, but up to 2500 kHz may be authorized upon showing of need. Under Part 90, all services are permitted to use the band for either base or mobile stations; no channelization is set forth in the rules. The same grandfathering clause as in Part 94 is noted under each of the many services provided in Part 90 for this band.

The Commission's Master Frequency Index shows 137 stations in the 2483.5-2500 portion of the band with grant dates prior to July 25, 1985. Of these, 89 are for video service with emission designators ranging from 16000F9 to 18000F9, and licensed typically to broadcasters and ETV operations under Part 74, Broadcast Auxiliary Services. Section 74.602 channelizes various portions of the band from 1990 to 2500 MHz in 17-MHz segments; 4/ footnote NG147 is cited to indicate the license restrictions applicable to users in the 2483.5-2500 MHz portion of the band. The remaining 48 licenses are held by various oil companies with emission designators ranging from 200KF8W to 800KF8W (there is one F9W). In all cases, the modulation is FM and the information is most likely FDM/FM telephony and a combination of this together with digital data. We demonstrate below that the RDSS operation proposed by **CELSAT** can co-exist with these services, even at the increased level of power-flux density that is requested in this petitioned.

The NTIA assessment (op cit.) for the 2025-2300 MHz band characterizes typical auxiliary broadcast stations in the following manner:

1 to 5 hops
2 to 12 watts Tx power
20 dBi antenna gain
4 to 8 dB receiver noise figure
8 to 30 MHz IF bandwidth
-88 dBm threshold for 33 dB SNR 5/

For the video link analysis, we assume a typical 10-mile single-hop "reference" system by selecting from among the NTIA characteristics and adjusting to the actual systems licensed in the 2483.5-2500 MHz band. The reference system is chosen to be a 10-watt transmitter with a 20-dBi antenna at each end, a 6-dB noise figure receiver having a 18-MHz IF bandwidth and a -88 dBm threshold for a barely acceptable picture (33 dB video SNR).

At 2500 MHz the free-space loss is 124.6 dB and the received power is -47 dBm, allowing for 2.4 dB miscellaneous losses. The noise floor set by the receiver alone is

$$-114 \text{ dBm/MHz} + 10 \log(18 \text{ MHz}) + NF = -95.5 \text{ dBm}.$$

The typical video SNR for such an FM-video system is given as the sum of the CNR and the receiver transfer function, which in turn is the sum of FM improvement and noise and pre-emphasis weighting factor usually taken at 13 dB. For the system described the RTC is between typically 28 and 31 dB, depending on the amount of "over-deviation" permitted. 6/ A system operating in northern CONUS that is oriented so that its path azimuth is approximately equal to the azimuth arrival angle to a satellite operating co-channel will suffer some noise floor degradation from the satellite signal. For CDMA transmissions, the interference will appear only as additional front-end thermal noise and thus behaves as the most "benign" form of interference, to use Viterbi's phrase. Transmissions at the existing pfd limit will have an effect estimated as follows:

The elevation angle to a satellite at one of **CELSAT**'s proposed northern CONUS service areas will be 20 degrees. The first sidelobe of a 20-dBi antenna is at 24 degrees off the main beam. As a worst case, assume that the video system is located sufficiently south of the northern border to view the satellite at an angle equal to this sidelobe angle. The sidelobe is typically 18 dB below the main lobe but a more conservative value is that given by the sin(x)/x function for a uniformly illuminated aperture, 13 dB. Thus the gain towards the satellite is 7 dBi while that towards the desired signal is 20 dB. The capture area of a 7-dBi antenna at 2500 MHz is 22.4 dB below that of a 1 sq-meter aperture. The interference power received from the satellite is thus:

$$-144 \text{ dBW/sq-m/4-kHz} - 22.4 = -166.4 \text{ dBW/4-kHz}.$$

In the same reference bandwidth, 4 kHz, the receiver-alone noise is calculated as:

$$-144 \text{ dBW/MHz} + 6 \text{ dB (NF)} - 10 \log(1 \text{ MHz}/4 \text{ kHz}) = -162 \text{ dBW/4kHz}.$$

Summing the receiver-alone noise with the satellite noise-like interference, we find a rise in the noise floor of 1.34 dB. For **CELSAT**'s proposed pfd relaxation to the pfd limit of 6 dB, the increase in the noise floor is estimated by summing the receiver-alone figure with -160.4 dBW/4-kHz to obtain a 3.9-dB increase. Thus, **CELSAT**'s proposed pfd limit relaxation introduces about a 2.6-dB increase in the noise floor of the victim receiver. The effect of this on the reference system must next be examined. Since the system was receiving its intended signal at a level of -47 dBm, the video SNR expected will be as shown for three cases, assuming a median RTC of 29.5 dB:

case 1	no RDSS satellite :	CNR = 48.5 dB	SNR = 78.0 dB
case 2	RDSS sat at pfd limit :	CNR = 47.1 dB	SNR = 76.6 dB
case 3	RDSS sat at pfd + 6 dB:	CNR = 44.6 dB	SNR = 74.1 dB

In all cases, the calculated SNR will exceed that available from video sources 7/ and these calculated SNRs for the reference system would not be achieved in practice.

Assume that the fade margin is that required to deliver a "broadcast quality" signal; i.e., a margin of 25, 23.6, or 21.1 dB, for the three cases, respectively. Using the Barnett/Vigants model 8/ for non-diversity outages over an "average" terrain path during an "average" month, the expected fading to delivering broadcast quality with no margin results in dropping below this level for periods of 33, 18, or 13 seconds per month for the three cases. Thus, the incremental "outage" is 13 seconds per month if **CELSAT**'s 6-dB relaxation of the pfd limit is permitted against a 10-mile video link under the worst-case path orientation with respect to one of **CELSAT**'s satellites. If outage to the threshold SNR of 33 dB is used as a criterion, the outage times for all three cases are less than one-third second per month, while still maintaining a "usable" picture.

The typical Part-94 fixed-service receiver was characterized in the NTIA report as follows:

1200-deg K noise temperature

40 hops in a typical system, 30 km each hop
36 dBi max antenna gain
14 dBrnc0 interference threshold
FDM/FM modulation

Further characterization from the license information in the MFI for the 2483.5-2500 MHz band would have the emission bandwidths at 800kHz or less, gains of 30 dB average, and single-hop systems. We take as a reference system a 12-channel analog FDM/FM telephony link with a 20-mile single-hop path using 30-dBi antennas, a 60-watt eirp, and a receiver with a 7-dB noise figure (1200 deg K) and a 800 kHz IF bandwidth. Again, the path is oriented to receive the maximum interference from an RDSS satellite.

At 2500 MHz the free-space loss is 130.6 dB and the received power is -46 dBm, allowing for 3.2 dB miscellaneous losses. The noise in a derived voice channel should be less than 58 dBrnc0 to achieve a SNR of 30 dB (a somewhat lower value is used in public networks but all licensees are providing private service). The derived noise is given by the expression:

$$\text{dBrnc0} = -C - 48.1 + NF - 20 \log(df/fch),$$

where C is the carrier power, NF is the noise figure, df is the peak deviation of a channel carrying a signal of test-tone level, and fch is the center frequency of a channel in the baseband group (the top channel is used to estimate noise levels, in a 12-channel group this is 106 kHz and the deviation is typically 70 kHz). For the reference system the derived noise is 8.7 dBrnc0 and the system is operating well below the acceptable noise limit.

The interference from an RDSS satellite is now estimated. The highest sidelobe peak, offset from the main beam in a 30-dBi gain antenna, is at 28.6 degrees and its gain 20.8 dB below that of the peak, or 9.2 dBi; the corresponding capture area at 2500 MHz is

-20.2 dB sq-meter. For a satellite operating at the pfd limit, the received noise is -164.2 dBW per 4 kHz. For a 7-dB noise figure receiver, the noise in the same bandwidth is -161 dBW/4 kHz. The sum of these is -159.3 dBW and the noise figure is effectively raised by 1.7 dB. For **CELSAT**'s proposed pfd relaxation of the pfd limit by 6 dB, the received noise is -158.2 dBW per 4 kHz. The sum of these is -156.4 dBW and the noise figure is effectively raised by 4.6 dB. The contribution of the noise figure to the derived noise in a baseband channel is linear and the noise is still well below the acceptable level of 58 dBrnc0. Furthermore, the contribution of an RDSS satellite operating at the pdf limit or 6 dB above the limit is well below the interference threshold of 14 dBrnc0. Fading to the 58-dBrnc0 limit will occur for less than 1 second per year over the 20-mile path for satellite interference at 6 dB above the pfd limit.

It should be noted that the derived noise will be governed primarily by intermodulation among the 12 voice channels and not by either the receiver's noise figure or the RDSS interference level. During fades, the IM noise drops and the thermal plus satellite interference will become more of a factor. But for the reference system assumed, the fade depth to the noise floor set by the satellite interference is still below the 40-dB depth that most systems are designed to, and the outage time to 40-dB would not be affected by the increase in noise floor. Similarly, the derived voice-channel noise is governed mainly by the IM, typically at the 30-40 dBrnc0 level. The rise in the noise floor when the path is aligned with an RDSS satellite could not be detected by a listener.

The NTIA assessment concluded that an increase in pfd by 10 dB would not be detrimental to the existing systems in the 2025-2300 MHz band. There are long-haul systems having many hops in this band as well as vulnerable aero telemetry systems. Neither of these systems are licensed in the 2483.5-2500 MHz band and the NTIA report's conclusions would most likely have been more liberal if it

The Part-22 control and repeater operations can be modelled adequately by the 12-channel, single-hop system analyzed supra for RDSS downlink band interference. There it was shown that raising the pfd limit by 6 dB would have a neglibile effect on such operations. Thus again, the analysis shows that the incremental interference to terrestrial systems in the 2110-2130 MHz band is minimal. **CELSAT** therefore further requests that the Commission should grant the request for relaxation of the pfd limit by 6 decibels from -144 dBW to -138 dBW/sq-m/4-kHz for the proposed system operating in this band.

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1. "Assessment of Satellite Power Flux-Density Limits in the 2025-2300 MHz Range," Part 2, NTIA, July 1984, NTIS # PB85-101244

2. Power levels were noted as the contents of the ovens were varied from empty, 1/4-cup water, full cup water, and two quarts water. All measurements cited herein used 1/4-cup water which was boiling when data were taken.

3. As of November 20th, 1991, 22 grants were made for devices employing spread-spectrum modulation in the 902-928 MHz band which, like the 2400-2483.5 MHz band, is authorized for SS systems that are permitted to radiate as much as 4 watts, eirp (see Section 15.247). Given this level of grant activity, systems operating in the higher band may be anticipated, in spite of the microwave ovens in this band. We note that the 2483.5-2500 MHz band is a restricted band under Section 15.205. A typo in the 15.205 table as published in 47 CFR defines the lower edge of the restriction as 2438.5 MHz, rather than the correct frequency, 2483.5 MHz.

4. The licenses of concern here are for 16-MHz channels in the 2484-2500 MHz band.

5. Presumably perceived video SNR

were conducted in the RDSS band. **CELSAT** is proposing less relaxation of the pfd limit than 10 dB in a band where only systems less vulnerable are licensed. The effect of a higher pfd on these systems was demonstrated above to be small and will be even smaller on systems not near the northern border or that are not aligned with azimuths near those of the two proposed satellites. For these reasons, and the public interest in granting a satellite system with such large capacity (lower costs), the Commission should grant the request for relaxation of the pfd limit by at least 6 decibels from -144 dBW to -138 dBW/sq-m/4-kHz.

Operation in a Proposed Generic MSS Band

The effects of an increase in the pfd limit for **CELSAT**'s system on other systems in the generic MSS downlink band at 2110-2130 MHz is analyzed in this section. This band will be proposed by the US delegation to WARC-92. 9/ Terrestrial operations in this band are limited to Part 21 Fixed Point-to-point Microwave service and Part 22 Control and Repeater stations. Part 21 channelization is limited to 3.5 MHz maximum and to 800 kHz in Part 22. 10/

The Part 21 fixed-service operations are used primarily for long-haul rural telephony trunking and cellular system cell-site interconnection. This application closely fits the hypothetical reference circuit defined in CCIR Recommendation 390-3 and is used as the analysis model in the NTIA assessment. 11/ The results of the analysis are presented in Table 9 in the assessment, except that a 3-dB correction factor for a receiver transfer function was not applied. Leaving aside this correction because it applies to interfering signals that are not spectrally smooth and noise-like, the Table-9 pfd limits can be increased by anywhere from 8.1 to 14.5 dB, depending upon the average latitude of the path and the spacing of similar satellites along the orbital arc; the values cited are for a 20-degree spacing and **CELSAT**'s spacing would greatly exceed this.

6. Overdeviation is said to occur when the Carson's rule bandwidth is exceeded; that is, greater than twice the sum of the composite base bandwidth and the peak deviation.

7. High-quality studio cameras attain SNRs of 60 dB or slightly more; "broadcast" quality images are said to be those with SNRs exceeding 53 dB.

8. See BSTJ, 51, No. 2, 1972 and BSTJ, 54, No. 1, 1975.

9. WARC-92 Preparation Inquiry in Gen Docket 89-554, June 20, 1991, at 58-67.

10. The 2110-2120 MHz band is also shared with deep-space research operations in the earth-to-space direction. Footnote US252 limits this service to Goldstone CA. It appears to be the general consensus that this service is compatible with an MSS service in the space-to-earth direction; see id. at 37-38.

11. op. cit., p. 16.

APPENDIX -- D

APPENDIX D

CELSAT INTERFERENCE ANALYSIS & COMPATIBILITY WITH OTHER SYSTEMS

The compatibility of applicant's proposed system with other systems in both the preferred bands of operation, 2.4/2.1 GHz, and the alternative bands of operation, 1.6/2.4 GHz, is discussed in this appendix. Most of the discussion and analysis in the downlink direction is contained in Appendix C as the demonstrations of compatibility and the levels of interference are related to the requested relaxation of power flux density.

Proposed Uplink Band

Applicant's proposed uplink band of operation is in the 2410-2428 MHz band. This is in the upper half of the 40 MHz band from 2390-2430 MHz that the US delegation to WARC-92 will propose for generic MSS in the earth-to-space direction. Currently, this band is shared by government radiolocation systems and amateur services. The government allocation is primary and is limited to military systems by footnote G2. The amateur services include the amateur-satellite service. As these services have secondary status they are not considered further in this analysis.

Analysis of the compatibility and the potential for interference with military systems will be conducted by Celsat if the Commission makes the characteristics and locations of the systems available. We note that, in its report on the WARC-92 preparation inquiry, the Commission did not cite any DoD comments concerning the US proposal that the band be allocated for non-government mobile-satellite services. From this it is inferred that a problem in sharing the 2390-2430 MHz band with military systems operating in the 2390-2450 MHz band does not exist.

Alternate Uplink Band

As an alternative to the 2410-2428 MHz band, applicant requests that its operations be located in the RDSS band, 1610-1625.5 MHz. Compatibility and the potential for interference to and from systems in the various services now occupying this band are discussed infra.

The US proposes to upgrade the Radio Astronomy (RA) service in the 1610.6 to 1613.8 MHz band to primary status; this would be effected by modification of ITU footnote 734. 1/ No US footnote to the 2.106 table identifies RA operations at any of the radio astronomy observatories or other facilities for the 1.6-GHz band such as those mentioned for other bands in FNs US111, US203, US256, US257, and US311. However, the NAS/Geostar agreement offers guidance in this regard. 2/ Applicant's proposed division of the uplink band into subbands will assist in preventing harmful interference to spectral line observations by avoiding use of the lowest subbands in areas in which RA may be operating. Applicant's uplink operations do not actually use the lowest 1 MHz of the band and begin at 1611 MHz, dividing the spectrum above this into 1.25-MHz subbands. The proposed subband assignment is dynamic and flexible; the lowest three subbands will not be assigned during periods of RA operation in affected areas. In this manner no transmissions will occur below 1614.75 MHz. Time sharing of the RA band has been suggested. 3/ Celsat's transmission modes make time sharing of the RA band infeasible and no attempt to take this approach will be made. In this manner, Celsat's operations will not decrease RA observation time in the 1.6-GHz band. Celsat's proposed ground channels and access channels are located at the upper edge of the band and will not interfere with RA operations. Applicant can modify operations rapidly, on short notice, to accommodate temporary RA operations at any location, and will design the Celsat system to avoid harmful interference with any existing or future permanent RA operations within any of its service areas. Note that applicant will use the 1.6-GHz band only for ground user terminals and will not conduct space or airborne operations in this band that, as FN 734 observes, are "particularly serious sources of interference" for the RA service.

The US WARC-92 delegation is empowered to protect the Soviet Global Orbiting NAvigation Satellite System (GLONASS) if it operates above 1610 MHz. 4/ This would appear to be the case; ARINC states that GLONASS operates at ten center frequencies in the band from 1610.44 to 1615.5 MHz. 5/ It transmits spread-spectrum modulation in wideband (P) and narrowband (C/A) modes similar to the US' Global Positioning System (GPS) at a signal level of -44 dBW/Hz with RHC polarization. 6/ The P-code transmission mode has its first spectrum nulls at +/- 5.11 MHz, the C/A mode operates at one-tenth the P-mode rate and its spectrum is scaled accordingly. GLONASS will be used on US aircraft to supplement GPS for navigation. In addition, GLONASS and GPS may be used at US airports to monitor runway activity and thereby avoid collisions between departing or landing aircraft and ramp service vehicles. The potential for harmful interference from handhelds operating at 1.6 GHz is examined infra with respect to navigation aboard aircraft; interference with ground-based receivers for collision avoidance will be less severe because the excess path losses will be greater than that assumed in the analysis for an aircraft above the ground.

GLONASS satellites orbit at 19,200 km and transmit to earth using 13-dB isoflux antennas. ARINC Characteristic 743A 7/ requires the aircraft receiver to track a GLONASS signal received at the -139 dBm level subject to in-band interfering signals 13 dB above this level, or at -126 dBm.8/ The aircraft antenna gain is not specified below its local horizon, at which point the gain is specified to be at most -5 dBi; this value is used as a worst case since the path to a handheld will be below the local horizon except when the aircraft is banking in the direction of the handheld. Applicant's typical handheld will, when communicating with a satellite, transmit with a net EIRP of -9 dBW, or +21 dBm. The aircraft's navigation receiver will use the GLONASS C/A signal and will require approximately 0.5 MHz bandwidth. A handheld will have a subband spectrum about twice this and a 2:1 bandwidth advantage is given to the navigation receiver when estimating the potential for interference.

At a 1-mile horizontal separation from an airborne GLONASS receiver, the handheld signal is received at a level estimated as:

Pr = +21 - 116 (path loss) - 5 (gain) -3 (advantage) = -103 dBm.

The path loss is the per-mile free-space value at 1610 MHz plus 15 dB excess path loss for an assumed aircraft altitude of 30 meters (about to land or taking off). The excess interference level is the difference between the -103 dBm level and the acceptable level of -126 dBm. The 23 dB excess is eliminated at a separation of about 6 miles, assuming a 30-dB/decade propagation law. 9/ For aircraft at higher altitudes, the excess path loss will diminish, approaching 0 dB above an elevation angle that will be related to the nature of the surrounding terrain. But at higher elevation angles, the entry angle to the aircraft's GLONASS antenna falls below the horizon. For lack of more detail concerning the aircraft antenna's gain below the horizon, it is assumed that the two factors, excess path loss and sub-horizon antenna gain, offset one another and the 6-mile separation holds for all handheld/aircraft aspects. Thus, a handheld operating near an airport may cause harm to navigation if the aircraft cannot use the US' GPS system that operates outside the 1.6-GHz band. This is a matter for additional study but can be alleviated by operating handhelds in subbands above 1615.5 MHz when near GLONASS receivers. In any event, in light of the demise of the Soviet Union and the subsequent financial problems of the CIS, reliance upon GLONASS for US domestic operations, especially those relating to public safety, is misplaced and will probably diminish. The third-generation Inmarsat system to be launched in 1995 will have a GPS/GLONASS "overlay" capacity that will provide an alternative to GLONASS. Further, use of the US' GPS system could provide twice the location accuracy if the "selective availability" imposed by the DoD is suspended. 10/

GLONASS' interference to Celsat's satellite transponders may cause harm, based on the following examination. The worst case approach between a GLONASS satellite and that of Celsat occurs when a GLONASS satellite is on the opposite side of the earth from a Celsat satellite. For a Celsat beam serving Anchorage, the squint angle to the earth's limb is within the main lobe of a beam centered on Anchorage and is approximately 10 dB down from the maximum gain of 46.6 dBi. The beamwidth of the GLONASS antenna exceeds that required to subtend the earth from limb to limb and an orbital arc of many degrees will exist during which the excess beamwidth can illuminate the Celsat satellite and create substantial interference. At a typical separation of 66,000 km, the interference density is -191 dBW/Hz at the Celsat antenna terminals and is about +37 dB with respect to Boltzmann's constant, thereby raising the system noise temperature from a nominal 528 degrees K to over 5000 degrees K. The self noise from a fully loaded satellite cell ranges from -186 to -181 dBW/Hz, depending on the activity in adjacent cells. The interference can reduce the nominal 1.7-dB margin on the return link (handheld to node) by from 0.4 to 1.2 dB. The situation is worse if two or more of the planned 21 GLONASS satellites are in view of the geostationary satellite. Since the GLONASS carrier spacings are 0.5625 MHz and the C/A-mode spreading bandwidth is about 1 MHz, there is a likelihood of interference overlap into one of the Celsat 1.25-MHz subbands. This interference problem can be avoided by assigning only subbands above 1616 MHz in Celsat's northern-most beams.

GLONASS officials are reported to be aware of these problems; in subsequent system designs they will not use carriers above 1610 MHz and will take actions to protect the geostationary arc. Such remedies are not available in the short term, however.

International footnote 733 allocates the 1610-1626.5 MHz band to the aeronautical mobile-satellite (R) service on a primary basis, worldwide. The potential for interference from applicant's use of this band can be estimated as follows: Assume an AMS(R) satellite having an antenna that views all of CONUS and therefore having a gain of approximately 30 dB. Assume a 10-kbps data channel and a satellite reception bandwidth of 20 kHz using a receiver with a 3-dB noise figure. The noise floor is -158 dBW. Assume that the encoding and modulation are such that the required CNR is +6 dB for the specified data bit-error rate. If the AMS uplink is operating with no remaining margin the desired signal is received at a -152 dBW level. If all of applicant's 60,900 satellite channels are in use, the worst-case interference level will occur. In any of the ten subbands there will be 5,700 channels, each in view by the AMS satellite, and each with an nominal EIRP of -9 dBW. The total uplink interference power is -9 + 10 log 5700, or +28.6 dBW. The effective power inband at the AMS receiver is adjusted by the ratio of Celsat user spreading bandwidth to the reception bandwidth, or by -18 dB (ratio of 20 kHz to 1.25 MHz); the effective interference power is therefore +10.6 dBW. The path loss to the AMS satellite is 188 dB and the received power is +10.6 -188 +30, or -147.4 dBW. The C/(N+I) level for the assumed 0-margin operating point is -4.6 dB. However, there are several mitigating factors to consider. If there is a difference in polarization type between the AMS link and the Celsat link (which is RHC) at least 3 dB improvement can be realized. The AMS link may be operating above its 0-dB margin, and, further, all 57,000 Celsat channels are not likely to be active at the same time. Applicant will take care to coordinate with any and all AMS(R) systems that may be proposed or come into being in order to ensure the integrity of each such system.

Compatibility with other systems and the potential for harmful interference from applicant's system in the downlink direction in the 2110-2130 MHz band and in the 2483.5-2500 MHz band are discussed and analyzed in Appendix B.

* * * * *

1. WARC-92 Preparation Inquiry in Gen Docket 89-554, June 20, 1991, at 42.

2. Six observatories were identified in the agreement, two in California, one each in New Mexico, Texas, West Virginia, and Puerto Rico. A 25-km protection radius must be observed during periods of observation in the 1610.8-1613.8 MHz band about geographical coordinates specified for each of these sites. The Celsat emission characteristics and user geographical density are different from those of Geostar and the protection radius may differ from the 25-km value arrived at in the Geostar agreement.

3. Avoiding transmissions during the first 200 milliseconds of each Coordinated Universal Time second allows the radio observatory to gather line-spectrum data and has been authorized as a method of coordination; see Appendix D of RDSS Report & Order, July 25, 1985, in Gen. Dockets 84-689 & 690.

4. WARC-92 Preparation at 41.

5. According to ARINC in its Reply Comments of July 3, 1991 to the Iridium and Ellipsat applications.

6. Dale & Daly, "The Soviet Union's GLONASS Navigation Satellites," IEEE AES Magazine, May, 1987, pp. 13-17.

7. Draft copy informally obtained; 743A is yet to be published and therefore the specifications cited supra are subject to change.

8. The GLONASS spreading sequence is 511 bits; we assume a processing gain for the GLONASS receiver equal to its despreading bandwidth reduction, or 27 dB. This would account for the ability of the receiver to operate while subject to interference at a -13-dB I/C level.

9. This is in agreement with the propagation model shown as Figure 2-8 in Lee (Mobile Communications Design Fundamentals, Sams & Co., 1986). An average between the open-area and suburban-area excess loss at 1 mile is about 10 dB for a mobile antenna at 3 meters height and a 30-meter base station antenna height. Adjusting for the proposed operating frequency and the lower height at which a pedestrian user would hold the handheld, an additional 5 dB should be ascribed to the excess loss.

10. GPS has twice the spreading bandwidth of GLONASS and similar parameters otherwise. Hence the temporal resolution is twice and should translate to approximately twice the location accuracy. Selective availability deliberately reduces the inherent accuracy to less than that obtainable from GLONASS.

APPENDIX -- E

APPENDIX E

CELSTAR HPCN RADIO LINK POWER BUDGETS

Link budgets for both the satellite links and the ground links that together comprise the hybrid system that Celsat proposes in its application are presented in this appendix. These calculations are included to support the Petition by virtue of their constituting concrete and realisitc examples of the proposed system performance and operation.

SATELLITE LINK POWER BUDGET

Satellite link power budgets are shown in Tables E 2-17. These 16 tables cover the combinations of:

Alternate A /Alternate B Frequency requests
Two Satellites (Nominal)/One Satellite (Emergency) mode
Hybrid Satellite-Ground/Satelite Only operation
Prime power/Flux Density limited operation

The link budgets are structured such that the bottom-line independent variable is the number of US voice grade (or equivelent composite digital rate) circuits that can be supported. This bottom line is summarized for the 16 cases in Table E-1 below.

The system uses four types of satellite links. The satellite-to-user links are referred to as "mobile" using S and/or L-Bands, while the satellite-hub or "backhaul" links are in K- band. The direction from hub-to-satellite-to-mobile is called "forward" while the reverse is "return". The tables include the up and down components of the "Forward" (i.e. hub-to-mobile) and "Return" (mobile-to- Hub) links.

The satellite transponders act as "bent pipe" repeaters. There is no on-board signal processing. The resulting noise level as received on the ground includes transponded downlink noise and interference as well as the downlink power contributions. However, the backhaul links are less critical and the system design is such that their effect on received SNR is condsidered negligible. Of the two mobile links, the downlink, satellite-to-mobile is far the more power critical and flux-density critical and is the principal determinant of system capacity.

Table E-2 may be taken as the baseline case, representing two satellites serving the US, using frequency alternate A; this case is prime-power limited in the preferred Hybrid Space-Ground mode. Both satellites provide for full coterminus US (CONUS) coverage so that on an operational basis the sharing can be either on a cell-by-cell or split-CONUS basis. There will be some advantage in serving a given cell with that satellite providing the higher elevation angle (i.e. nearer in longitude). The table values (except for total CONUS capacity, circuits per beam, and total system self-interference) are for either one of the two satellites. Fully loaded capacity for US service including Alaska, Hawaii and Puerto Rico/Virgin Islands is 54,295 circuits.

Table E-3 shows the fallback mode, in the event of complete failure of one satellite, the other will take over service for the complete CONUS at reduced circuit capacity. Overall US capacity in this case is 34,740 circuits.

The power budget analysis includes adequate allowances providing the grade-of-service goal for each identifiable source of anomalous fading or noise. Consequently, any positive bottom line margin is excess margin. The analysis operates to reduce this bottom line excess margin to zero dB, thereby implicitly solving for the maximum supportable number of circuits per cell [line 11].

The significance of the various items in the link budget are discussed infra, and are identified by row number in the following discussion, with reference to Table E-2, the baseline mode. The principal design driving parameters are listed in the header area of each table.

7. DC POWER IN TO MOBILE DOWNLINK: (2300 W) This is the total Prime DC power allocated to the satellite-mobile Downlink, the principal power consumer in the Satellite power budget. Total satellite end-of-life DC Power is 4.3 kW.

7. SPREAD BANDWIDTH (15.0 Mhz) for the mobile downlink. The mobile uplink uses another such allocation. This consists of 12 contiguous sub-bands of 1.25 MHz, each.

8. SAT-MOBILE S-BAND DOWNLINK AMPLIFIER EFFICIENCY, (.35) Overall DC-to-RF conversion efficiency.

8. BACKHAUL BANDWIDTH (150.0 MHz). The product of Allocated Bandwidth and Backhaul Multiplex Factor [line 12]. This utilizes a frequency multiplex of the various cell composite signals onto the backhaul link.

9. MOBILE DOWNLINK RF POWER (805 W). The product of input power and efficiency. This is a primary constraint and eventually determines the circuit capacity that can be supported.

9. FAST FADE DEPTH: (4.0 dB). The duplex mobile link incorporates two-way transmitter power control to partially overcome the effect of ground obstruction (trees, buildings,etc). Each circuit of each link provides for an additional transmit power headroom of 12 dB above average for this purpose. However, that power is seldom used so the average power, important for battery and CDMA system self-noise considerations is essentially the unfaded link line-of-sight value. For the mobile-to-satellite uplink, this compensation will work almost perfectly (1 dB), the residual error being due mostly to frequency dispersive multipath and the difference between up and down link frequencies. For the satellite-to-mobile downlink, however, the measured signal strength is already 1/4-second in the past when measured at the hub,

signal strength is already 1/4-second in the past when measured at the hub, and 1/2-second old when it encounters the supposedly same ground fading obstruction on the downlink. Consequently, the downlink compensation will only be partially successful in removing the higher-frequency components of fading, with time constants less than 1/2 second. The fast-fade depth represents the estimate of *average* additional power allowance for fast-fading that will *not* be compensated by this method but will be invoked on demand by the power control system. The same compensation covers the backhaul links, but there the fading (e.g. rain attenuation) is very slow and is assumed essentially perfect (<1 dB residual). Individual backlink transmitters will provide a power headroom of 13 dB above average, but since it is very improbable that two backhauls will be in maximum rain fading at once, the overall satellite power consumption is essentially unaffected.

10. # OF US CELLS (112). This results directly from the main antenna beamwidth, line 20, and the design choice of 3 dB major cell diagonal crossover point as shown in Figure ???. These determine the individual cell area and, in turn, the number of cells for CONUS coverage. This also provides near inshore coverage of the surrounding ocean areas to an average of 1/2 cell diameter or about 60 miles offshore and includes three cells dedicated to Hawaii, Alaska, and Puerto Rico/Virgin Islands.

10. DATA RATE, 5kbs. This comprises 4800 bps voice encoding multiplexed with a 200 bps supervisory and power control data stream.

11. # CIRCUITS PER CELL: (485). This is a derived number, the maximum number that can be accommodated with the given power, with adequate signal/noise ratio, and resulting in a positive forward link margin, as summarized in lines 13 and 14.

11. # OF SATELLITES FOR CONUS COVERAGE. Two for this case. Primary RDSS service is provided from each satellite to all cells via a carrier that is approximately 13 dB down from the communications carrier. Communication service is provided from each satellite to the nearer half of CONUS.

12. NUMBER OF CODE DIVISION GROUPS PER CLUSTER (10) (Backhaul Multiplex Factor). Each backhaul link serves this number of cells. The "cluster" for these purposes is the group of cells served by a backhaul link and does not imply a frequency reuse group as in fdma cellular telephone systems. Each cell comprises a Code Division (CD) group. Ten CD groups are frequency multiplexed

together for the backhaul to form a frequency division group serving a "cluster" of ten cells.

13. CLUSTERS PER CONUS (12). This determines the number of ground hubs. There is a great deal of flexibility in this aspect of the design.

13. EXCESS FORWARD LINK MARGIN (0.0 dB). This is *"excess"* margin, i.e. after presumed adequate allowance for all anticipated marginal effects such as fading and implementation imperfections. This is driven to zero dB, i.e. power is fully utilized, by choice of number of channels.

14. # of 1.25-MHz SUBBANDS PER GROUP. (12). The total occupied band is divided into 1.25-MHz subbands in order to maintain compatibility with the emerging CDMA de facto standards and in order to afford a degree of flexibility to respond to local interference problems. There is no loss of overall capacity in this breakdown by subbands. The total satellite system bandwidth includes an additional 1.25 MHz subband devoted to a broadcast pilot and a total of six additional 0.125-MHz call service channels not treated in this power budget.

14. RETURN LINK EXCESS MARGIN (3.2 dB). This is somewhat greater than minimal because power is not critical for this link. The return link is designed for a better grade of service so that system will almost always limit first on the critical forward link.

17. FREQUENCY: Alternate A frequencies are the new WARC-92 proposed generic mobil-sat allocations in S-Band. Alternative B frequencies are those allocated to RDSS, 2483.5-2500 MHz MHz downlink and 1610-1626.5 MHz uplink. The backhaul frequencies are in K-Band and non-critical.

18. SATELLITE REFLECTOR DIAMETER. (20 m) The critical mobile link uses the largest dish currently known to be feasible, 20 meters, since the number of circuits that can be supported for a given authorized bandwidth and power, and the overall frequency utilization efficiency increase roughly with the reflector area.

For the backhaul links the diameter is chosen, non-critically, to provide a beam-width not less than that of the most directive mobile link so as to not pose a special pointing or station-keeping problem.

19. ILLUMINATION FACTOR. (0.49) This is the fraction of the feed energy lost to spillover past the sides of the dish. The figure is a near optimum

compromise between power loss in spillover and loss of directive gain that would result from a more compact illumination.

20. 3 dB BEAMWIDTH (0.51/ 0.44 deg) for the critical S- and L-Band user links.

21. CELL MAJOR DIAMETER. (0.51 deg). Major diameter means the largest diameter of the hexagonal cell structure. This is set to the downlink 3 dB major diameter and is a near-optimum compromise between loss of gain and interference spillover. The same geographic cell structure is used for the uplink in order to simplify handover logistics. This means that the cell diameter determined is greater than optimum for the uplink. However, the uplink is non-critical so the loss is not significant. This is equivalent to about 204 statute mile major diameter in a plane normal to the beam at the latitude of central CONUS.

22. MAJOR DIAMETER CROSSOVER LOSS. (3.0 / 3.9 dB). This is at the major diameter. The corresponding minor diameter crossover loss is about 2.1 dB for the downlink.

23. AVERAGE OFF-CENTER LOSS. (2.0/2.6 dB). This is the loss of directive gain averaged uniformly over the cell, as compared to that at beam center. The average rather than maximum loss is appropriate here since link power control levels each channel individually and this power budget is for the average (or total) of such levelled channels. Note that the non-optimal cell size results in an advantage of some 0.6 dB to the downlink in this respect. However, this is just about made up for by the improved inter-beam interference factor, line 25.

24. AVERAGE IN-CELL GAIN (47.8 / 48.4 dB). This is taking into account the average off-center loss, item 23.

25. TOTAL BEAM INTERFERENCE FACTOR: (BOF, 2.4/1.9 dB). Since all users share the same frequency band but with different spreading codes, all users interfere with one another as random noise, attenuated in power by beam directivity and the spreading code processing gain. For any user, the principal interference on both up and down L-Band links comes from users within the same beam cell. However, some interference arrives via sidelobes from other cells. Assuming uniform distribution of user locations, typical beam directivity pattern, and individual link received power levelling, the total other user interference from the same and adjacent beams or cells is found by numerical integration to be a factor +2.4/+1.9 dB relative to the